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INTEGRATED BIOLOGICAL STATUS OF FRASER RIVER SOCKEYE SALMON (*ONCORHYNCHUS NERKA*) UNDER THE WILD SALMON POLICY

Sockeye Salmon adult spawning phase. DFO website.

Figure 1: Sockeye Salmon spawning locations in southwestern BC.

Context

Canada's Wild Salmon Policy's (WSP) identifies six strategies for implementation. Strategy 1 is "Standardized monitoring of wild salmon status" and requires biological status assessments for all Pacific Salmon conservation units (CUs). To conduct WSP status assessments, a toolkit comprised of a number of classes of indicators and metrics for status evaluation was completed in 2009. However, since a number of metrics can be used to evaluate biological status, it is possible that each metric can indicate a different status (Red, Amber, or Green). Therefore, status integration, which includes synthesis of CU status information across metrics into one or more status zones, and the provision of expert commentaries on the information used to assess status, is a useful final step in the status designation process. Previously, no methodology for status integration has been developed for the WSP. This paper, therefore, presents the first exploration of WSP status integration conducted in a recent CSAS workshop: "Guidelines for Aggregating Status Indicators and Their Application to 24 Conservation Units of Fraser River Sockeye". This workshop builds upon a previous CSAS publication that presents uncertainty in WSP status for Fraser Sockeye CUs.

This Science Advisory Report is from the November 14-16, 2011 meeting on the Guidelines for Integration of Wild Salmon Policy Biological (Strategy 1) Status Indicators and their Application to Fraser River Sockeye Conservation Units. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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SUMMARY

- The 24 Fraser Sockeye CUs were used as case studies to explore methods of status integration for Strategy 1 of the Wild Salmon Policy (WSP): *Standardized Monitoring of Wild Salmon Status*. Although most of these case studies represent data rich CUs in the Pacific Region, with long time series of stock-recruitment data, a few Fraser Sockeye CUs are also data limited (e.g. Chilliwack-ES has only some recent spawner abundance data).
- Status integration was evaluated during a three day technical workshop, which included the development of both final status designations for each Fraser Sockeye CU and commentaries on the information used to assess status. This work completes WSP status determinations for Fraser Sockeye, which follows up on the recently published exploration of uncertainty in WSP status metrics for these CUs (Grant et al. 2011).
- For the workshop, two-page standardized data summaries were produced for each Fraser Sockeye CU. Summaries included WSP status information for a number of metrics (e.g. relative abundance, short-term trends in abundance, and long-term trends in abundance) and other biological data relevant to their interpretation.
- CU data summaries were grouped into three different sets of case studies: two sets for non-cyclic CUs and one set for cyclic CUs. Case studies were evaluated 'blind', with generic labels rather than CU names. The decision to evaluate case studies 'blind' was made to facilitate the development of a standardized WSP status integration approach, to focus discussion on the metrics presented in Grant et al. (2011) for status integration, and to facilitate discussion between experts with detailed local and CU-specific knowledge and those with broader salmonid and status evaluation experience.
- For each of the three case study sets, the workshop was structured to include a combination of small group sessions (four to six participants per group) and plenary sessions (all 34 workshop participants).
- On the final day of the workshop, the integrated status for each CU, developed in the previous days' plenary sessions, was re-visited with the goal to reconcile group results into a final single status zone, where possible, and to fine tune status commentaries.
- Also on the final day of the workshop, CU names were revealed to provide participants with the opportunity to introduce any specific supplementary information that might support a change in the integrated status designation, or that could be added to the CU status commentaries.
- Final integrated status for each of the 24 Fraser Sockeye CUs included the following: seven Red, four Red/Amber, four Amber, two Amber/Green, five Green, one Data Deficient, and one Undetermined. Detailed status results for each of the groups and expert commentary (which identified key metrics and associated data that guided these status determinations) are published separately, and are necessary for CU status interpretation in WSP Strategy 4.
- Integrated status determination for cyclic CUs presented the largest challenge to participants. Specifically, the appropriate method for estimating benchmarks for the relative-abundance metric of cyclic CUs was debated. Since this issue could not be resolved at the workshop, these metrics for cyclic CUs were excluded from status evaluations. The unique population dynamics of these CUs further added complexity to cyclic CU status evaluations.

- Although each group moved through the CU summary information in different sequences, there was considerable similarity amongst groups regarding which considerations drove their final integrated status determinations.

INTRODUCTION

The goal of the Wild Salmon Policy (WSP) is *'to restore and maintain healthy salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity'* (DFO 2005). In order to achieve this goal, the WSP outlines a number of strategies, including Strategy 1 (Standardized Monitoring of Wild Salmon Status), which is the subject of this SAR. Action Steps for Strategy 1 include: (1) identification of CUs; (2) development of criteria to assess CUs and identification of benchmarks to represent biological status; and, (3) monitoring and assessment of CU status. Work on these action steps has progressed since the WSP was published in 2005, with the following peer-reviewed milestones:

- methodology for the identification of Pacific salmon CUs (Holtby and Ciruna 2007);
- methodology for the assessment of Pacific salmon biological status under the WSP (Holt et al. 2009);
- technical background for WSP status assessments (Holt 2009; Porszt 2009; Holt 2010; Holt & Bradford 2011; Porszt et al. 2012);
- uncertainty in WSP status for Fraser River Sockeye salmon CUs (Grant et al. 2011);

Four classes of indicators have been recommended to evaluate WSP status of wild Pacific salmon: abundance, trends in abundance, distribution and fishing mortality (Holt et al. 2009). Within each class of indicator, one or more metrics can be used for status assessments and, for each metric, a lower benchmark and upper benchmark delineate, respectively, the Red to Amber and Amber to Green status zones (Table 1). These biological benchmarks are specifically used for status assessments, and are not prescriptive for specific management actions. They are also designed to be more conservative than the criteria established by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), as required by the WSP.

Table 1: Three zones of biological status defined in the WSP (WSP p. 17 & 18)

Status		Definition
	Red	"... established at a level of abundance high enough to ensure there is a substantial buffer between it and any level of abundance that could lead to a CU being considered at risk of extinction by COSEWIC"
	Amber	"While a CU in the Amber zone should be at low risk of loss, there will be a degree of lost production. Still, this situation may result when CUs share risk factors with other, more productive units"
	Green	"identif[ies] whether harvests are greater than the level expected to provide on an average annual basis, the maximum annual catch for a CU, given existing conditions...there would not be a high probability of losing the CU"

Since CU status evaluations can include more than one metric, it is possible that different metrics could each indicate a different WSP status zone from Red (poor status) to Green (healthy status). For example, the WSP recent trends in abundance metric could suggest a CU's status is poor, while conversely, the long-term trend metric could indicate the same CU's status is healthy. In cases where metric information is contradictory, provision of this metric-specific status information alone does not provide complete scientific advice to fisheries management. Instead, a final step that synthesizes all metric and status-related information into an integrated status for each CU, and provides expert commentary on this information, is necessary as inputs into subsequent implementation of WSP Strategy 4 (Integrated Strategic Planning) to prioritize assessment activities and management actions (Table 2).

For Pacific Salmon CUs, WSP biological status integration methods have not previously been developed. Therefore, in the absence of existing WSP-specific status integration approaches, a CSAS workshop: "Guidelines for Aggregating Status Indicators and Their Application to 24 Conservation Units of Fraser River Sockeye" was conducted to achieve this goal. This SAR summarizes the results from this recent CSAS workshop.

Table 2: Guidance in the WSP on assessment actions and management considerations for CUs in each status zones (DFO 2005: p. 17-19, 26, 32)

Status		Assessment Actions	Management Considerations
	Red	"... a detailed analytical assessment will normally be triggered to examine impacts on the CU of fishing, habitat degradation, and other human factors, and evaluate restoration potential", "... detailed stock assessments will identify the reasons for the change in status". "CUs in the Red zone ... will be identified as management priorities ... the protection and restoration of these CUs will be primary drivers for harvest, habitat, and enhancement planning."	"Biological considerations will be the primary driver for the management of CUs with Red status". "The presence of a CU in the Red zone will initiate immediate consideration of ways to protect the fish, increase their abundance, and reduce the potential risk of loss".
	Amber	"... a detailed analytical assessment may be required to input into Strategies 2 & 3.."	"Decisions about the conservation of CUs in the Amber zone will involve broader considerations of biological, social, and economic issues"; "involves a comparison of the benefits from restoring production versus the costs arising from limitations imposed on the use of other CUs to achieve that restoration"; "implies caution in the management of the CU"
	Green	" a detailed analytical assessment of its biological status will not usually be needed"	"Social and economic considerations will tend to be the primary drivers for the management of CUs in the green zone, though ecosystem or other non-consumptive values could also be considered".

ASSESSMENT

Data

For the workshop, two-page standardized data summaries were produced for each Fraser Sockeye CU. Data and status results were updated from Grant et al. (2011) to include 2010 spawner abundance information. These data summaries included the following:

- status information for up to four WSP metrics: one relative abundance, one long-term trend in abundance, and two short-term trend in abundance metrics (note: relative-abundance metrics could not be evaluated for CUs without recruitment or carrying-capacity data)
- presentation of both structural (i.e. model form) and stochastic (i.e. unexplained recruitment variation) uncertainty in relative-abundance-metric benchmarks and status
- presentation of relative-abundance-metric status evaluated using either geometric or arithmetic averages of recent abundances
- qualitative summary of overall data quality
- time series figures of productivity (recruits/spawner)
- time series figures of spawner abundance
- table of absolute abundances relative to COSEWIC criteria D1 for small populations
- retrospective (historical) time series of status for each WSP metric
- supplementary time series figures of fishing mortality and total recruits

Method

The 24 Fraser Sockeye CUs were used as case studies to explore methods of WSP status integration. Status integration was evaluated in a three-day CSAS workshop. This workshop included the development of final integrated status for each CU (which could include one or more WSP status zones), and expert commentaries on the data used to assess status. In addition, status integration approaches were developed. Workshop participants included technical experts that represented different areas of stock assessment expertise: Fraser Sockeye CUs, other Pacific salmon CUs, fisheries management, and broader salmon research.

At the workshop, CU case study sets, comprised of standardized CU data summaries (see previous Data section), were provided to participants immediately prior to the start of each break-out session. Case studies were organized into 17 non-cyclic CUs and seven cyclic CUs. Cyclic CUs were identified based on three considerations: relative goodness-of-fit for Larkin-type models compared to Ricker-type models, expert opinion on the life history of each CU, and visual inspection of the observed patterns in abundance (see Grant & Pestal 2012).

Each workshop participant was assigned to one break-out group (four to six participants per group) for the duration of the workshop, and groups worked through each case study set to develop both integrated single status (where possible) and commentaries for each CU, and document their approach to status integration. Case studies were evaluated 'blind', with generic labels rather than CU names. The decision to evaluate case studies 'blind' was made to facilitate the development of a standardized WSP status integration approach, to focus discussion on the metrics presented in Grant et al. (2011), and to facilitate discussion between experts with detailed local and CU-specific knowledge and those with broader salmonid and status evaluation experience.

Following each break-out group session, a plenary session was conducted with all 34 participants to record individual group results and commentaries for each CU in the case study set, and status-integration approaches. Plenary sessions also facilitated early discussions between groups on their integrated statuses and commentaries. On the final day of the workshop, integrated statuses for each CU, developed in the previous days' plenary sessions, were re-visited with the goal to narrow down a CU's status to a final single status zone where possible. However, if single status determination was irreconcilable between groups for certain CUs, the final integrated status could include multiple status zones agreed to by the full group at the final plenary session.

Also on the final day of the workshop, CU names were revealed to provide participants with the opportunity to introduce any specific supplementary information relevant to a CUs WSP status that could be used to rationalize a change to the integrated status or that could be added to the CU status commentaries.

Results

Final Integrated Status

In the final plenary discussion, participants reached broad agreement on integrated status designations for 22 of the 24 CUs (Table 3 & Figure 2). The 24 Fraser Sockeye CUs are ordered in Table 3 using their final integrated status, with CUs designated Red (poorest status) located at the top of the table to CUs designated Green (best status) at the bottom. Sixteen out of the 24 CUs were reconciled between groups in the final plenary session to a single WSP status zone. There were six CUs where final integrated statuses included two status zones. Both the Chilko-S and Lillooet-Harrison-L integrated Green status were flagged as provisional by participants, given these CUs have exhibited declining productivity and spawner trends in recent years. The Taseko-ES Red integrated status was also flagged as provisional, given spawner data for this CU are an index of abundance only and, therefore, this status designation was considered more uncertain. The integrated status of Chilko-ES was designated data deficient, as this CU does not have independent abundance data from the larger Chilko-S CU. Since the Chilko-ES CU contributes less than 10% to the total Chilko-ES/Chilko-S aggregate abundance, the aggregate status was assumed to represent the larger Chilko-S component. The integrated status of Seton-L was undetermined since final status amongst groups were widely divergent and remained unresolved through the final day's plenary session.

Most groups questioned the relative-abundance-metric benchmarks used for cyclic CUs (identified as cyclic in Table 3). Since this analytical issue could not be resolved at the workshop, participants agreed to exclude relative-abundance metrics for cyclic CU status evaluations during the final day's plenary session. The resulting integration approaches were similar to those developed for non-cyclic CUs with no recruitment data, and therefore, no relative-abundance-metric benchmarks. Participants pointed out that this still left more information for status assessments than what is available for many other Pacific Salmon CUs.

Status Commentaries

In addition to providing final integrated status for each CU (which can comprise one to two status zones), expert interpretation of the summary data used to integrate status was recorded as status commentaries (Appendix 2 of Grant & Pestal 2012). These commentaries provide the details underlying the final integrated status decisions, which varied even amongst CUs with identical status designations. These details will be important when these results from Strategy 1 (Standardized Monitoring of Wild Salmon Status) are linked to Strategy 4 (Integrated Strategic

Planning). Status zones on their own do not provide an indication of which factors drive their designation, which would influence subsequent WSP strategies (Table 2).

Status Integration Approaches

Groups were able to develop a consistent approach to integrate status information across individual metrics and supplementary information for Fraser Sockeye CUs. No single metric alone, in the absence of the consideration of additional metrics and supplemental biological information, drove the integrated status designation. The process was likened to checking a patient for symptoms, starting with key vital signs (i.e. the WSP metrics), and then scanning for other signs of any underlying problems (i.e. supplemental information).

Not all groups completed evaluations of all 24 CUs, but each CU was evaluated by several groups. While their broad approaches to integration differed, groups incorporated a number of considerations consistently:

- For non-cyclic CUs with recruitment data, one key piece of information relied upon by all groups was the WSP relative-abundance metric. This metric generally was given a higher weight in status determinations if a CU's relative-abundance-metric status was consistent across all benchmarks (i.e. across all models and probability levels presented). In contrast, if a CUs relative-abundance metric spanned multiple status zones, then groups frequently used the status indicated by the median (50%) probability level benchmarks, rationalized the selection of one particular model form, and relied more heavily on other metrics to determine status.
- Other metrics included in the previously developed WSP toolkit used to assess Fraser Sockeye status, including recent and long-term trends in abundance, did not influence status determinations consistently, and their interpretation by groups relied heavily on trends in CU productivity (recruits/spawner), abundance (spawners and returns), and fishing mortality.
- Of note, metrics not included in the previously developed WSP toolkit, such as absolute abundance (compared to COSEWIC criteria) and productivity trends, were important considerations in final status determinations.

Sources of Uncertainty

- Uncertainty in the underlying data and estimates for individual WSP metrics used at the workshop were previously reviewed and reported in Grant et al. 2011.
- At the workshop, status designations for cyclic CUs were considered more uncertain than those for non-cyclic CUs, given the exclusion of relative-abundance metrics from evaluations due to concern over the estimation of these benchmarks.
- Appropriate estimation of relative-abundance-metric benchmarks using time-varying model forms was also debated by workshop participants. Further, a recent evaluation of Fraser Sockeye productivity trends using an alternative model form (Larkin model), in addition to the standard Ricker model, reports different productivity trends for a few CUs (Peterman & Dorner 2012) from those presented at the workshop (based on Grant et al. 2011 results), which could influence status evaluations (i.e. Quesnel in particular).
- Given this was the first WSP status integration process, time spent on the final integration step (revealing the names of the CUs so relevant supplemental information could be added to the commentaries) was limited to ensure adequate time for participants to focus on completion of status assessments using the data summaries provided for each CU.

CONCLUSIONS AND ADVICE

Fraser Sockeye CU's Integrated Status

Integrated status designations were developed for 22 out of the 24 Fraser Sockeye CUs, and status commentaries were provided for all 24 CUs. These results address one of the two workshop objectives outlined in the Terms of Reference: "provide integrated status evaluations that include identification of relevant metric(s) used for the status determination for each of the 24 Fraser River Sockeye CUs". Integrated status designations for Fraser Sockeye CUs cover all three WSP status zones, ranging from Red (poor) to Green (healthy) (Table 3). Although single integrated status was not developed for all CUs, blended status (i.e. Red/Amber or Amber/Green) was still useful for relative CU ranking. There were two CUs where status could not be determined, either because the CU was data deficient, or due to contradictory status information that could not be resolved by workshop participants. Detailed status commentaries were also produced for each of the 24 Fraser Sockeye CUs and are documented in the associated CSAS Research Document (Appendix 2 of Grant & Pestal 2012; DFO 2012). The combination of integrated status designations and status commentaries is recommended for inputs into the subsequent Strategy 4 on strategic planning (Table 2).

Integrated status for the seven CUs designated Red and four CUs designated Red/Amber, represent the lowest biological status of the 24 Fraser Sockeye CUs. These CUs are generally naturally small in terms of abundance (Cultus-L, Bowron-ES, Taseko-ES, Widgeon-River-Type, Chilliwack-ES, and Nahatlach-ES), occupying a smaller geographic distribution, and/or were located higher up in the Fraser watershed (Takla-Trembleur-EStu, Bowron-ES, Quesnel-S, Nadina-Francois-ES, Francois-Fraser-S, Takla-Trembleur-Stuart-S) (Figure 2). In order of increasing biological status are the four Amber, two Amber/Green, and five Green CUs (Table 3). In contrast to the Red and Red/Amber designated CUs, these CUs tend to spawn lower in the Fraser watershed, both immediately upstream of Hells Gate (Shuswap, Chilko, Anderson-Seton systems) and downstream of Hells Gate (Harrison, Lillooet, and Pitt systems). The CUs in these systems also tend to have generally larger abundances and/or broader spatial distribution, compared to CUs in the Red and Red/Amber designations (Figure 3).

*Table 3: Integrated status designations for the 24 Fraser River Sockeye Salmon CUs, ranked from poor (Red zone) to healthy (Green zone) status. For each CU, more commonly used stock names are presented. Cyclic CUs are also identified. * indicates provisional status designations; R/A: Red/Amber; A/G: Amber/Green; DD: data deficient; Undet: undetermined.*

Status	Conservation Unit	Cyclic	Stock
Red	Takla-Trembleur-EStu	cyclic	Early Stuart
Red	Nadina-Francois-ES		Nadina
Red*	Taseko-ES		Miscellaneous Early Summers
Red	Nahatlatch-ES		Miscellaneous Early Summers
Red	Bowron-ES		Bowron
Red	Cultus-L		Cultus
Red	Widgeon – River		Miscellaneous Lates
R/A	Chilliwack-ES		Miscellaneous Early Summers
R/A	Francois-Fraser-S		Stellako
R/A	Quesnel-S	cyclic	Quesnel
R/A	Takla-Trembleur-Stuart-S	cyclic	Late Stuart
Amber	North Barriere-ES		Fennel & Miscellaneous Early Summer
Amber	Anderson-Seton-ES	cyclic	Gates
Amber	Kamloops-ES		Raft & Miscellaneous Early Summers
Amber	Harrison (U/S)-L		Weaver
A/G	Pitt-ES		Pitt
A/G	Shuswap-ES	cyclic	Scotch, Seymour, Misc.E.Sum.
Green*	Chilko-S & Chilko-ES agg.		Chilko
Green*	Lillooet-Harrison-L		Birkenhead
Green	Shuswap Complex-L	cyclic	Late Shuswap
Green	Harrison – River		Harrison
Green	Harrison (D/S)-L		Miscellaneous Lates
? DD	Chilko-ES		Chilko
? Undet.	Seton-L	cyclic	Seton

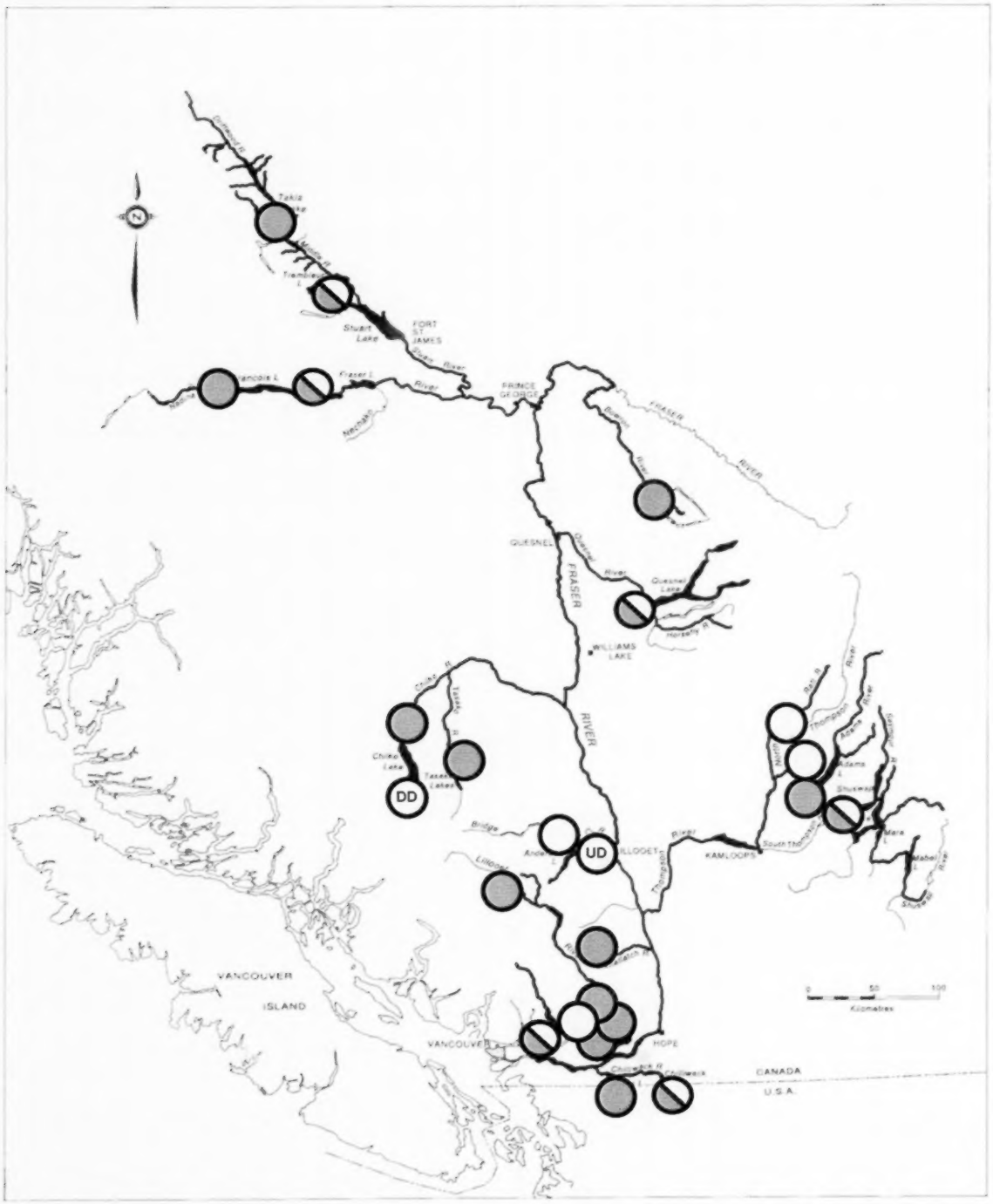

Figure 2. Map of the spawning distribution (darkened black lines) of Fraser River Sockeye CUs in south-western British Columbia with integrated status indicated for each CU (see previous Table 3).

Status Integration Process

Expert opinion on status integration and associated commentaries were elicited through a combination of smaller break-out group and full participant plenary sessions. The advantage of this approach was that it permitted independent small group evaluation of a range of integration approaches and integrated status designations, which could then be consolidated in a series of plenary sessions with all participants. Additionally, it provided the advantage of evaluating the robustness of status determinations through comparisons of independent group results (6 for each set of case studies). Although the size of the integration process, with 34 participants in a three day workshop, may not be feasible for covering all 450+ Pacific salmon CUs under the WSP, the general approach of independent versus full group work could be replicated with a smaller number of participants over a shorter period of time.

Integration Guidelines

The second goal for the workshop was "to develop clearly documented guidelines for combining information from different status metrics". Details on status integration approaches were broadly recorded for each group, and status commentaries developed in the plenary discussion capture the key pieces of status information used by groups to designate statuses for each CU. Based on the in-depth discussions at the workshop and the case-by-case nuances in metrics used and associated commentaries on the underlying data, it is not likely that a single prescriptive algorithm for status integration under the WSP can be developed. Rather, the CSAS workshop produced a process framework for status integration, and detailed guidelines for interpreting status-related information. Both of these elements are documented in Grant & Pestal (2012).

SOURCES OF INFORMATION

This Science Advisory Report is from the November 14-16, 2011 meeting on the Guidelines for Integration of Wild Salmon Policy Biological (Strategy 1) Status Indicators and their Application to Fraser River Sockeye Conservation Units. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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